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STRUCTURAL RESPONSE OF AN ADVANCED COMBUSTOR LINER: TEST AND ANALYSIS

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An advanced (segmented) combustor liner supplied by Pratt & Whitney Aircraft is being tested in the Structural Component Response Rig at Lewis. To evaluate the segmented liner's effectiveness and performance, we will compare the test results and analyses with those obtained from the conventional sheet metal louver liner, which was tested last year and reported at last year's HOST Workshop. The data obtained will also be used for verification of models and computational methods. The two liners compared had about the same heat flux. Obtaining the same heat flux required modest changes in the operating conditions for the segmented liner because of its larger diameter. About 500 thermal test cycles have been completed on the segmented liner. Each cycle is 2.2 min and simulates a take-off cruise and landing mission profile.

TEST LINER

The test liner, consisting of segments and an outer support shell to which the segments are attached, was instrumented with 125 thermocouples (TC's) - 73 TC's on the hot side of the segments and 52 TC's on the support shell. The instrumented liner is shown in figures 1 and 2. A grid system of lines of temperature-sensitive points was applied to over half of the segments in the liner to increase the area in which we could observe temperature changes. An infrared camera system is being used to obtain temperature maps of a portion of the outer shell of the liner through a quartz viewing window. Over the same field of view, high-resolution photographs of the outer shell are also being taken to determine the total strain during cycling.

RESULTS

Figure 3 is an isometric plot of the thermocouple temperature measurements of the hot side of the liner segments (which shows the cylindrical liner as if it were cut open and flattened out and shows a maximum temperature of 1400 °F at the maximum quartz lamp power (cruise) condition). Figure 4 is a similar plot of the outer shell which shows the maximum temperature to be about 600 °F. Transient data are also being obtained. The thermal point did not indicate a maximum temperature of more than about 1200 °F. The infrared data and the high-resolution photographs are being reduced and analyzed.

THERMAL/STRUCTURAL/LIFE ANALYSES

Three-dimensional thermal and nonlinear structural analyses of the conventional test liner and the segmented test liner were performed using the MARC finite element program. Eight-node three-dimensional solid elements were used to construct the liner models. The conventional liner model has 546 elements and 1274 nodes, and the segmented liner model has 536 elements and 1117 nodes.

Thermal analyses were first performed to obtain the transient temperature distribution in the liners. The same heat fluxes were applied to both liners. These temperatures were then used for the subsequent structural analyses of the liners. Both Walker and Bodner viscoplastic theories were used in the structural analyses. These theories account for the interaction between creep and plasticity. Results for the conventional liner were presented at the last HOST Workshop. Temperature, stress, and strain distributions for a symmetrical panel of the segmented liner at the maximum power level are shown in figures 5 to 7. The results showed that the critical stress-strain location in the segmented liner is at the retention loop. For the conventional liner, the critical location is at the seam weld. Based on the stress-strain and temperature at the critical location, the lives of both liners were assessed. The results are summarized and compared in table I. The estimated life of the conventional liner (400 to 1000 cycles) is based on limited published data, while tests showed liner cracking at the seam weld after 1500 cycles. Based on the limited number of tests and the preliminary analyses, the segmented liner will have a much longer life than a conventional liner because it has a lower operating temperature (about 400 °F lower) and no structural constraint in the circumferential direction.

CONCLUSIONS

The segmented liner is operating at much lower temperatures than the conventional liner (about 400 °F lower) for the same heat flux. At the lower temperatures and low thermal gradients, little distortion to the segments has been observed. Based on the test results and analyses, the operating conditions are not severe enough to distort or damage the segmented liner. In view of this, the next series of tests on the segmented liner will have more severe operating conditions such that they will result in increasing the liner hot-side surface temperatures to temperature levels consistent with those measured on the hot side of the conventional liner.

TABLE I. - SUMMARY OF STRUCTURAL-LIFE ANALYSES OF COMBUSTOR LINERS AT A CRITICAL LOCATION

(a) Conventional liner

Analytical method	Temperature range, °F	Strain range, με		Mean stress, psi	Predicted life, cycles
		Mechanical	Inelastic		
Unified (Walker)	950 to 1630	5870	3150	-35 000	400 to 1000
Unified (Bodner)	950 to 1630	5800	2700	-28 000	400 to 1000

(b) Segmented liner

Analytical method	Temperature range, °F	Strain range, με		Mean stress, psi	Predicted life, cycles
		Mechanical	Inelastic		
Unified (Walker)	755 to 1180	810	10^{-1}	10 000	$>10^6$
Unified (Bodner)	755 to 1180	820	10^{-1}	15 000	$>10^6$

SEGMENTED COMBUSTOR LINER INSTRUMENTED FOR TESTING

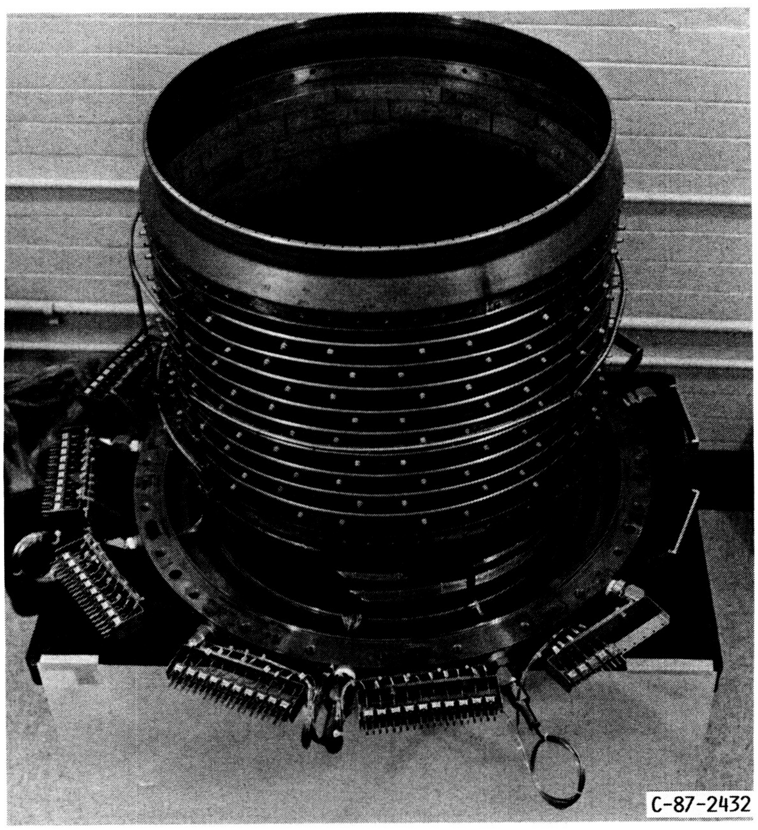

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Figure 1

SEGMENTED LINER SHOWING THERMOCOUPLES AND THERMAL PAINT GRID

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Figure 2

ISOMETRIC PLOT OF TEMPERATURE ON INSIDE OF SEGMENTED COMBUSTOR LINER

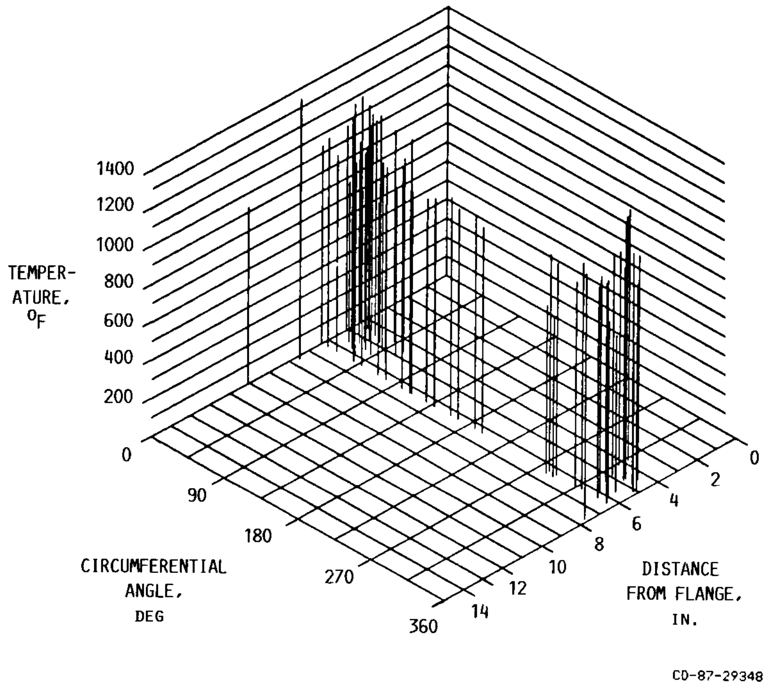

Figure 3

ISOMETRIC PLOT OF TEMPERATURE ON OUTER SHELL OF SEGMENTED COMBUSTOR LINER

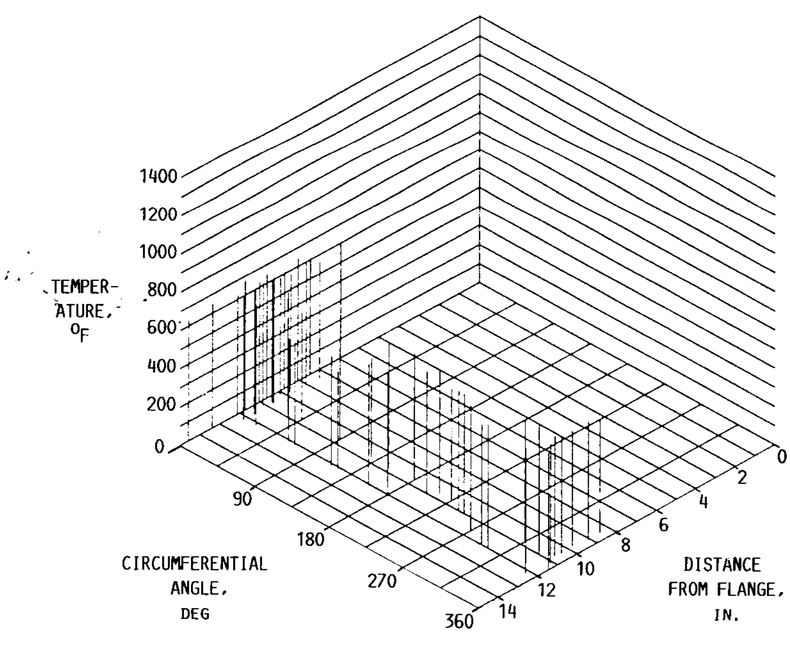

Figure 4

ADVANCED COMBUSTOR LINER TEMPERATURE DISTRIBUTION ON A SYMMETRICAL PANEL AT AN 83-PERCENT POWER LEVEL

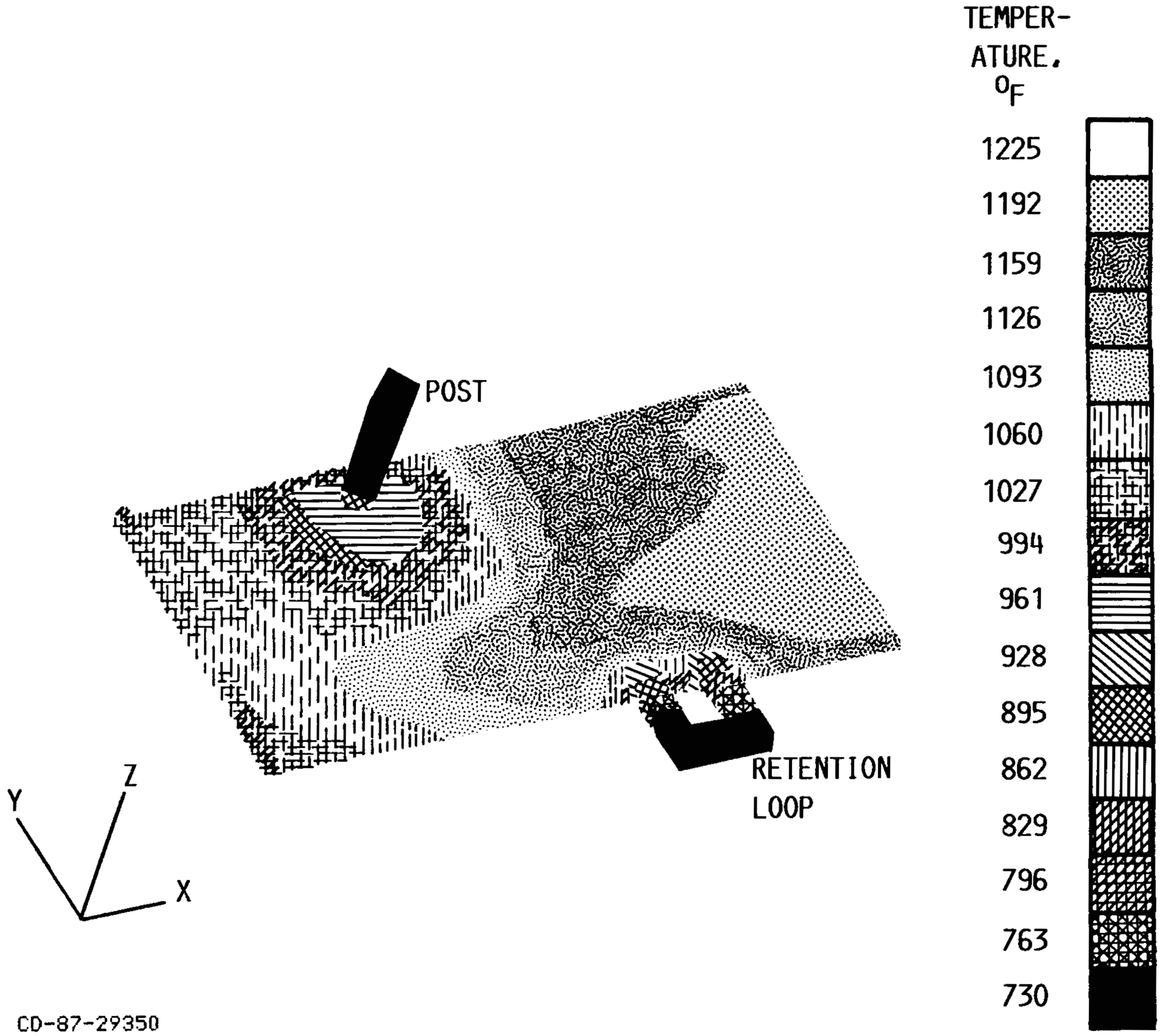

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Figure 5

ADVANCED COMBUSTOR LINER STRESS DISTRIBUTION ON SYMMETRICAL PANEL AT AN 83-PERCENT POWER LEVEL (X-DIRECTION)

VISCOPLASTIC CONSTITUTIVE MODEL: WALKER THEORY (3RD CYCLE)

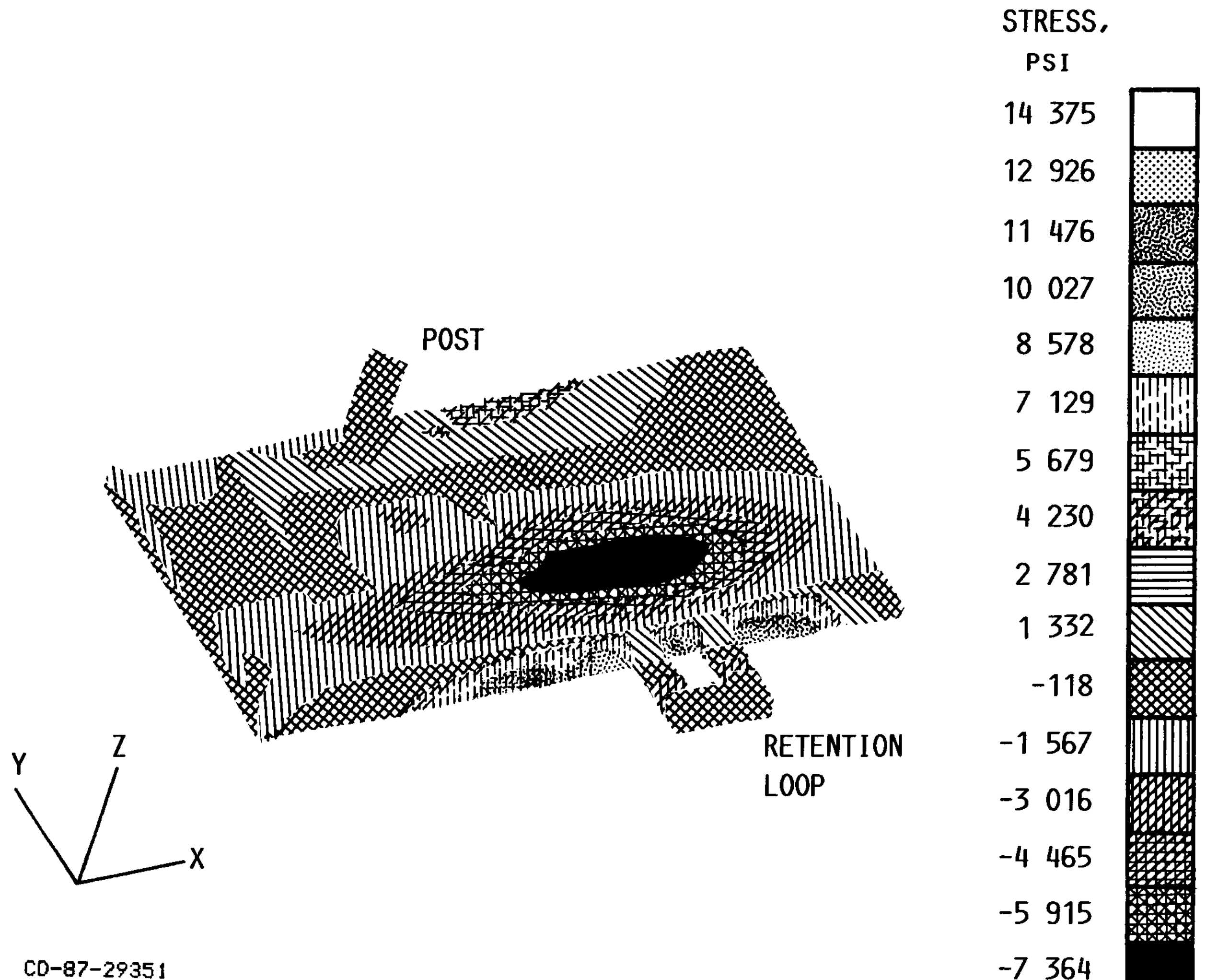

Figure 6

ADVANCED COMBUSTOR LINER TOTAL STRAIN DISTRIBUTION ON A SYMMETRICAL PANEL AT AN 83-PERCENT POWER LEVEL (X-DIRECTION)

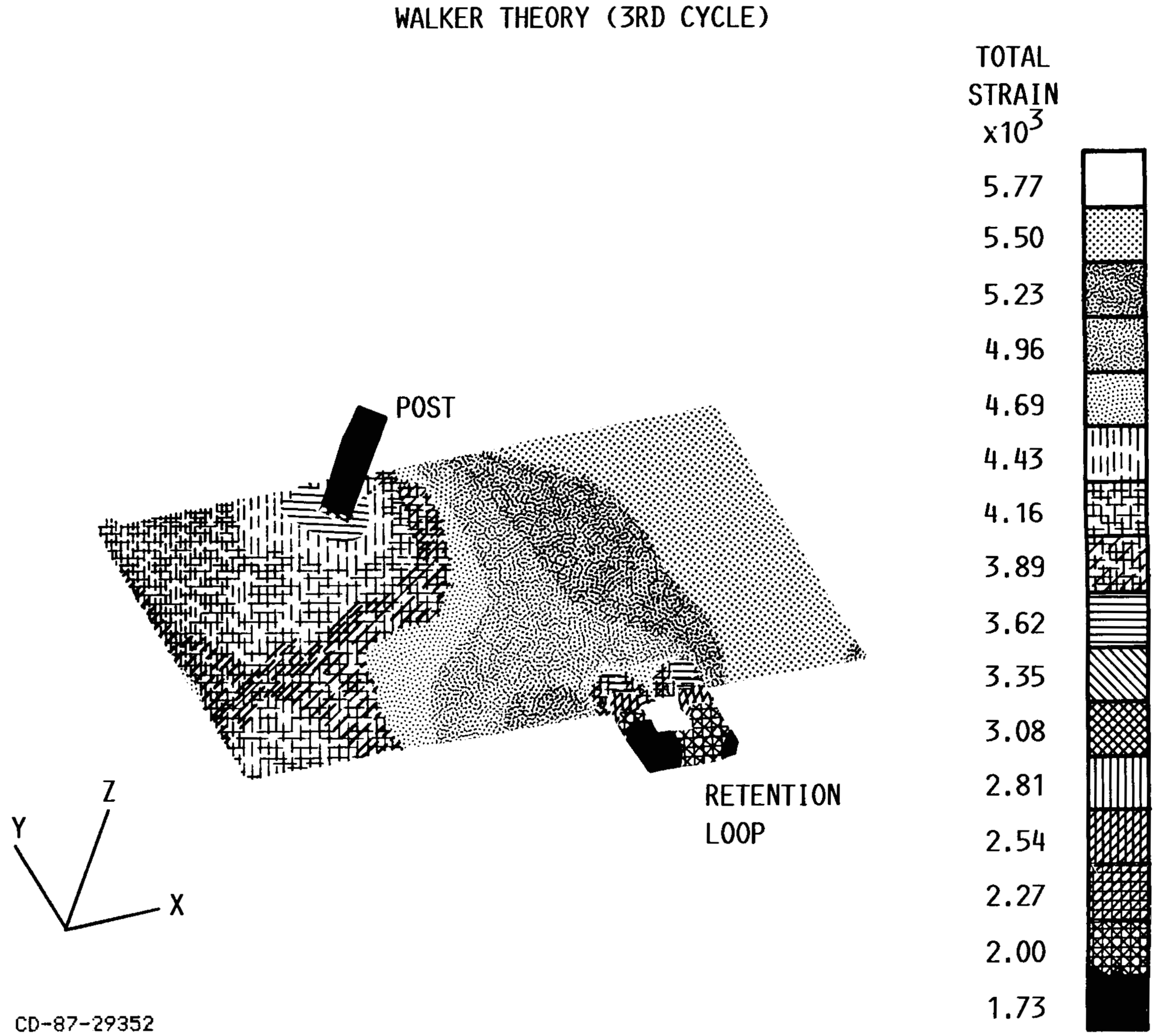

Figure 7